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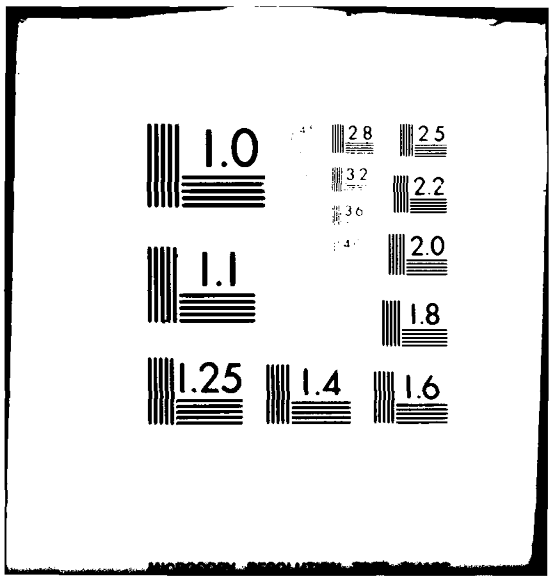
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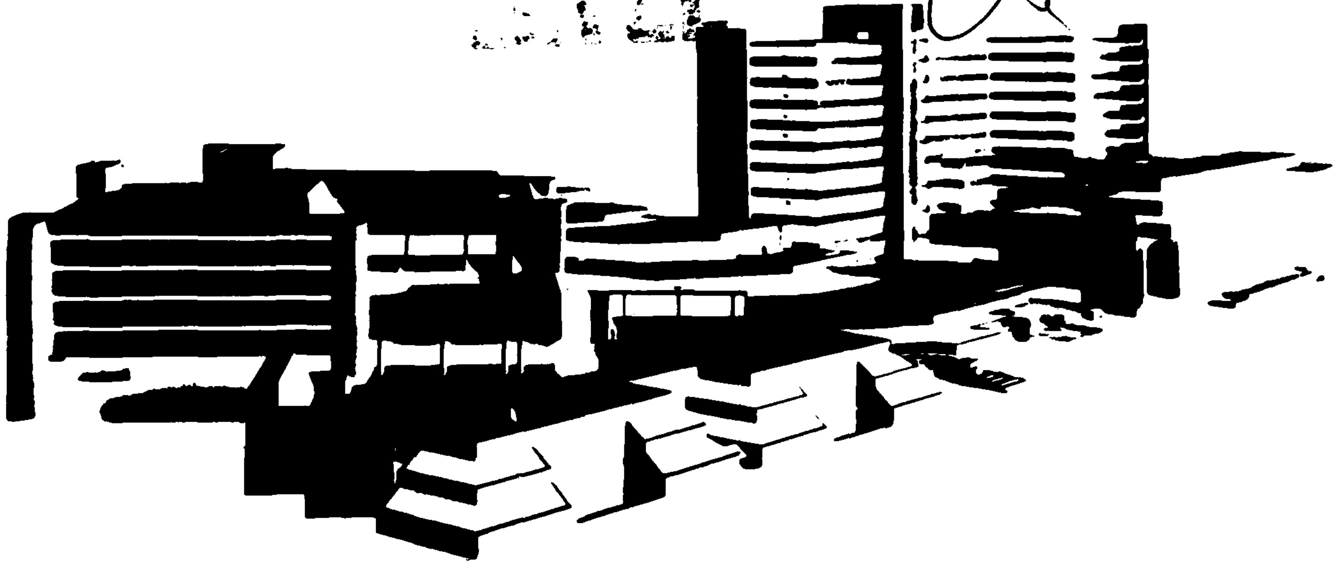

SEX DIFFERENCES IN FUNCTIONAL BRAIN ASYMMETRY

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ABSTRACT: Adult males show the expected pattern of verbal intellectual decline following left hemisphere lesions, and depressed nonverbal intelligence following right hemisphere lesions. In contrast, women do not show selective verbal or performance intellectual deficits after unilateral brain injury. These findings suggest a greater degree of functional brain asymmetry in men than in women.

In adult right-handers, damage to the left hemisphere of the brain is reported to disrupt language functions, whereas damage to the right hemisphere primarily affects nonverbal, visuospatial skills [1]. Thus, the term, "functional brain asymmetry" implies that the left hemisphere is specialized for verbal processes and that the right hemisphere is specialized for nonverbal functions [2]. According to a substantial body of literature these same lateralized functions are performed with differing degrees of ability by males and females. For example, females show superior verbal ability on word fluency and articulation measures, whereas males usually demonstrate superior spatial ability [3]. The fact that males and females differ in their performance of these functions raises the possibility that cerebral lateralization itself may differ according to sex.

Only recently has the relation of sexual phenotype to functional brain asymmetry been examined. Lansdell first reported that the nature of the cognitive deficit seen after unilateral temporal lobectomy depended not only on the side of the excision, but also on the reported sex of the patient [4]. Later studies by Kimura [5] and McGlone et al. [6] indicated that men showed a greater degree of right hemisphere specialization for spatial functions than did women. However, little is known about sex differences in the cerebral representation of verbal abilities.

This study examined both verbal and nonverbal intellectual abilities following left or right hemisphere lesions in males and compared them with females. Patients 15 to 70 years of age whose initial injury occurred after age 10 were tested. The sample consisted of 35 right-handers with unilateral brain injury admitted consecutively to the Neurology or Rehabilitation wards of of the University Hospital in London, Ontario from 1973 to 1975. Severe language disorders in 8 aphasics (6 men and 2 women with left hemisphere damage) precluded intellectual assessment. Thus, the data will be reported for 23 men and 20 women with left-hemisphere lesions, and 17 men and 17 women with right-hemisphere lesions. Localization of the lesion was based upon lateralizing signs reported in any of the following: neurological examination, brain scan, angiogram, electroencephalogram and/or operative note. No patient showed evidence of bilateral cerebral pathology and none had psychiatric histories. Vascular accidents (completed stroke or intracerebral hemorrhage) accounted for two-thirds of the sample, and the remaining third were diagnosed as tumor. Patients with transient ischemic attacks, arteriovenous malformations, seizures and closed head injuries were excluded because of the small N's in each group and the difficulties establishing duration and/or extent of brain injury.

The Wechsler Adult Intelligence Scale [7], was administered individually to each patient while in hospital. Calculation of the Verbal Intelligence Quotient (IQ) included all six subtests (Information, Comprehension, Similarities, Arithmetic, Digit Span and Vocabulary). However, Performance IQ was pro-rated on the basis of the following 4 subtests: Picture Completion, Block Design, Picture Arrangement, and Object Assembly. It was decided to exclude Digit Symbol from the Performance IQ of all patients because right hemiparetics were awkward in manipulating a pencil on this timed writing task. The patient groups were well matched on several variables believed to affect intelligence scores [8]. Thus, no significant differences appeared between males and females with left or right hemisphere lesions in: age ($\bar{X}$ = 43.5 years); education ($\bar{X}$ = 11.1 years); or length of illnes (vascular $\bar{X}$ = 4.5 months; tumor $\bar{X}$ = 32.7 months). Visual field defects and hemiparesis were similarly matched across groups.

An analysis of variance for unequal N's was performed on the intelligence scores diagrammed in Fig. 1. The four factors were: Side of Lesion (left, right), Sex (male, female), Etiology (vascular, tumor) and Task (Verbal IQ, Performance IQ). A significant Side by Sex by Task interaction ($F = 7.44$, 1, 69 df, $p<.01$) was further examined with *t*-tests.

Verbal IQ: Men with left-sided lesions obtained signficantly lower Verbal IQ scores than all other groups [9]. In contrast, women with left-sided lesions obtained a mean Verbal IQ (99.1) well within the Average range (i.e., 90 to 109 according to Wechsler's norms [7], and their scores did not differ from either women with right-sided damage ($t = 0.05$, ns) or men with right-sided damage ($t = 1.99$, ns). Thus, Verbal IQ deficits appeared only in men with left hemisphere lesions, findings which imply more asymmetrical, left-hemisphere control of verbal abilities in men compared to women.

As mentioned earlier, 6 men and 2 women were untestable on intellectual measures because of severe language difficulties. This sex ratio agrees with recent findings suggesting a higher incidence of aphasia in males after cerebral lesions [10]. To examine whether the lowered Verbal IQ seen in the 23 men with left-sided lesions was related to a greater degree of dysphasia than in their female counterparts, more basic measures of speech production were taken. Patients were asked to repeat words and phrases, name the months and name drawings of objects. On these elementary speech tests, men with left brain damage achieved 78% accuracy, which was not significantly different from the mean achieved by females with left brain damage (80%). In summary, men more often than women were rendered grossly aphasic by a left hemisphere lesion, and even when the dysphasia was mild and equal across the two sexes, men showed greater Verbal IQ deficits than women.

Performance IQ: The Performance IQ scores did not differ significantly according to sex or laterality of the lesion [11]. Although some studies [12] have reported Performance IQ deficits following damage to the right hemisphere only, several authors have found depressed Performance IQ after right, after left or after bilateral cerebral lesions [8,13]. Thus, left hemisphere damage may affect Performance IQ, although less than Verbal IQ.

Verbal-Performance Discrepancy: Within a single patient, however, one can measure nonverbal functions relative to language functions by taking a difference score between the Performance IQ and Verbal IQ. Fig. IIA depicts the mean discrepancy scores in graph form for each patient group. A positive value indicates higher Verbal IQ than Performance IQ, and a negative value indicates the reverse relationship.

Only men showed the expected pattern of Verbal or Performance IQ deficits depending upon the laterality of the lesion: that is, in men, left hemisphere damage impaired Verbal IQ much more than Performance IQ ($t = 4.85$, 22 df, $p<.001$), and right hemisphere damage lowered Performance IQ compared to Verbal IQ ($t = 3.43$, 16 df, $p<.01$). In women, Verbal and Performance IQ measures were not significantly different, whether the lesion was on the left ($t = 0.26$, ns) or on the right ($t = 1.04$, ns). These sex differences in the pattern of cognitive deficits related to unilateral cerebral injury suggest that the adult male brain is more asymmetrically organized than the female brain for both verbal and nonverbal abilities. It is important to emphasize here that etiological factors did not markedly alter the results (see Fig. IIB for vascular cases and IIC for tumor cases). Therefore, the findings reflect differences in underlying brain function rather than peculiarities in source of pathology or differing cerebral circulations.

Recent studies employing non-brain-damaged, adult populations provide confirming evidence, not only of greater functional asymmetry [5,6,14], but also of greater structural asymmetry [15] in the male brain. On the other hand, developmental studies indicate that girls show earlier and stronger lateralization of speech, motor and sensory functions compared to boys [16]. Left hemisphere dominance may, in fact, establish itself sooner in females, a maturational advantage which fits well with their reported superiority to males on certain speech-related tasks. Ultimately, however, the findings of the present study show that adult females appear to be less lateralized than males for verbal and spatial functions. Some conclusions can be made when the developmental and adult studies are considered together: (1) there are sex differences in the age at which cerebral specialization becomes evident functionally; (2) degree of functional brain lateralization depends upon sexual phenotype, in adulthood at least; and (3) sex differences may occur during the ontogenetic establishment of hemispheric specialization such that, over time, the male brain grows to be more asymmetrically organized (relative to the female brain).

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9. On Verbal IQ, left damaged males ($\bar{X} = 83.1$) scored lower than men with right-sided lesions ($\bar{X} = 106.8$; $t = 3.08$, 39 df, $p < .01$); lower than women with right-sided lesions ($\bar{X} = 98.9$; $t = 2.03$, 39 df, $p < .05$); and lower than women with left-sided lesions ($\bar{X} = 99.1$, $t = 2.26$, 46 df, $p < .05$).
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11. Males with left-hemisphere lesions obtained a Performance IQ of 94.3; males with right-hemisphere lesions scored 93.3; females with left-hemisphere lesions scored 99.2; and females with right-hemisphere lesions scored 94.7.
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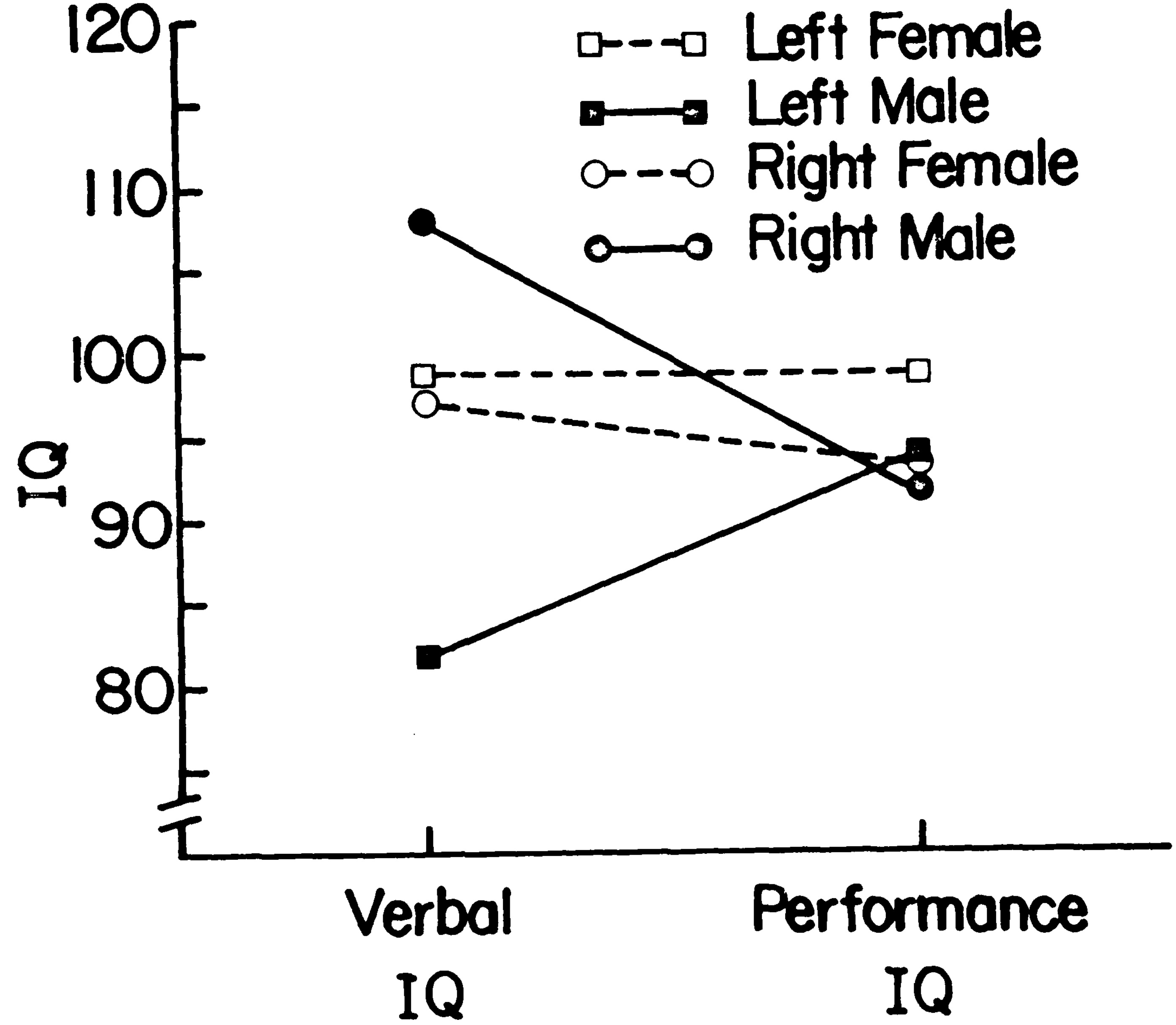
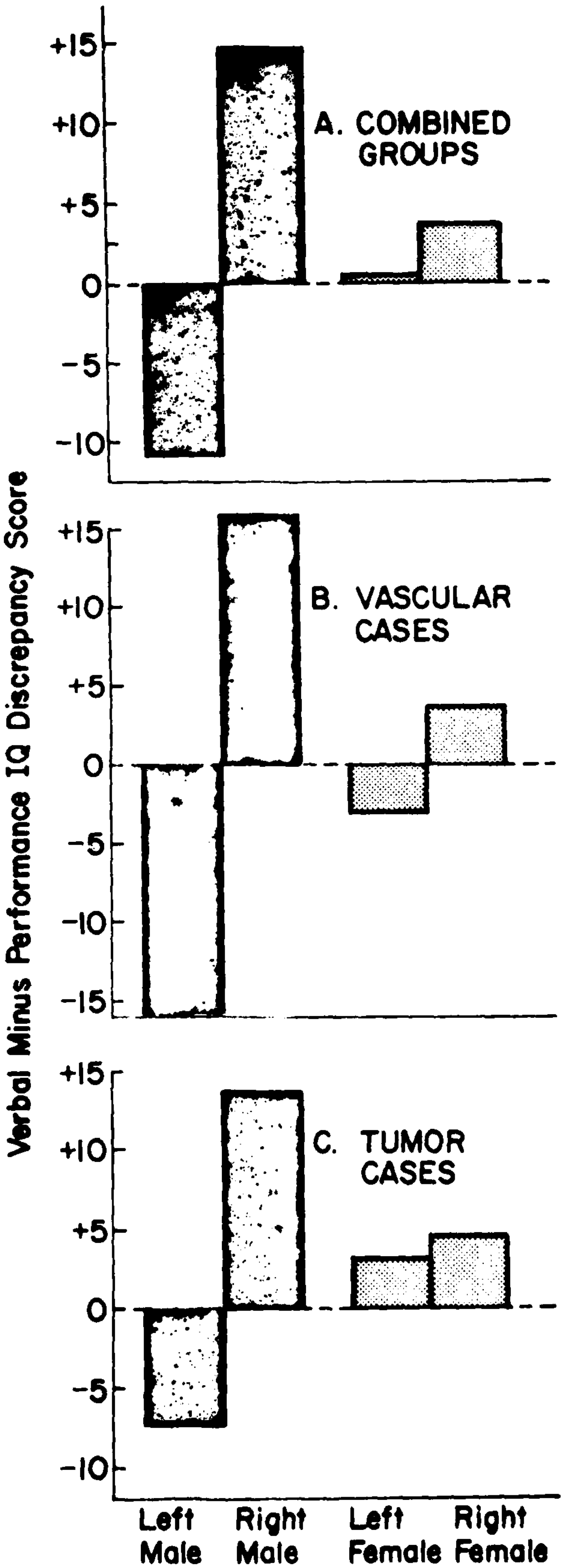
Fig. I. WAIS Verbal and Performance IQ scores in male and female patients with left or right brain injury.

Fig. II. WAIS Verbal minus Performance IQ discrepancy scores for male and female patients with left or right brain damage. A - Combined etiological groups. B - Vascular groups. C - Tumor groups.

FIG. 1



Left Female
Left Male
Right Female
Right Male
120
110
100
90
80
IQ
Verbal IQ
Performance IQ



Verbal Minus Performance IQ Discrepancy Score
+15
+10
+5
0
-5
-10
A. COMBINED GROUPS
+15
+10
+5
0
-5
-10
-15
B. VASCULAR CASES
+15
+10
+5
0
-5
-10
C. TUMOR CASES
Left Male
Right Male
Left Female
Right Female

FIG. 11

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